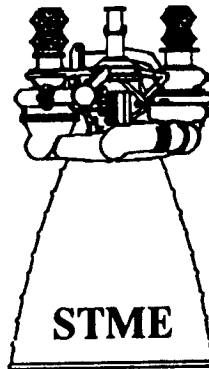


**N91-28271**

**PRESENTATION 4.4.9**

**SPACE TRANSPORTATION  
MAIN ENGINE**

**RELIABILITY AND SAFETY**



**SPACE TRANSPORTATION PROPULSION  
TECHNOLOGY SYMPOSIUM  
PENNSYLVANIA STATE UNIVERSITY**

**JAN C. MONK  
GEORGE C. MARSHALL SPACE FLIGHT CENTER**

**June 27, 1990**

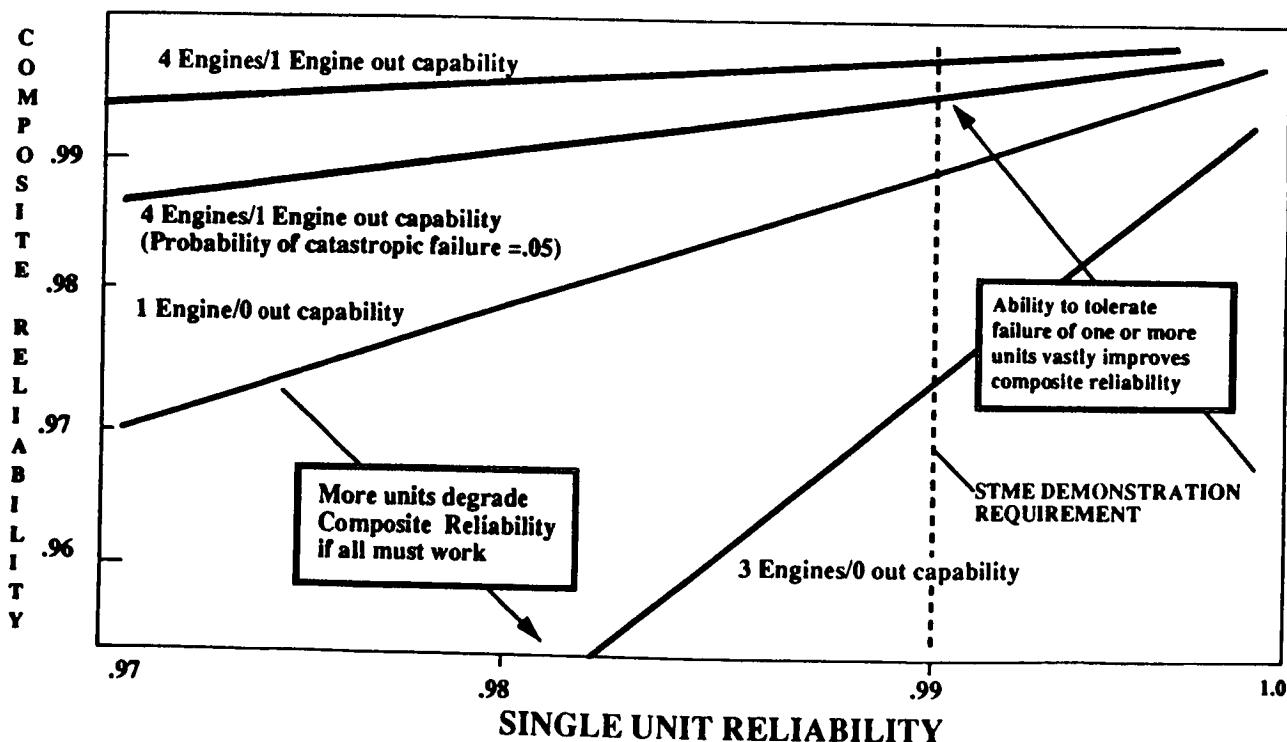
## STME RELIABILITY AND SAFETY

### ALS/STME APPROACH

- VEHICLE ENGINE-OUT CAPABILITY/HOLD DOWN
- EMPLOY TOTAL QUALITY MANAGEMENT
- SIMPLE, ROBUST DESIGN
- KNOWN CHARACTERISTICS

## STME RELIABILITY AND SAFETY

### Vehicle Engine Out Capability Provides A Significant Improvement In System Reliability



## **STME RELIABILITY AND SAFETY**

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### **TOTAL QUALITY MANAGEMENT (TQM)**

## **STME RELIABILITY AND SAFETY**

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**THE GOAL IS TO DEVELOP A ROBUST DESIGN**

### **STME QUALITY APPROACH**

```
graph TD; A[STME QUALITY APPROACH] --> B[DESIGN IT RIGHT]; A --> C[BUILD IT RIGHT]; B --> B1[CONCURRENT ENGINEERING]; B --> B2[VARIABILITY REDUCTION]; B --> B3[QUALITY FUNCTION DEPLOYMENT]; B --> B4[QUALITY ENGINEERING]; C --> C1[IN-PROCESS MONITORING]; C --> C2[STATISTICAL PROCESS CONTROL]; C --> C3[CONTINUOUS PROCESS IMPROVEMENT];
```

#### **DESIGN IT RIGHT**

CONCURRENT ENGINEERING  
VARIABILITY REDUCTION  
QUALITY FUNCTION DEPLOYMENT  
QUALITY ENGINEERING

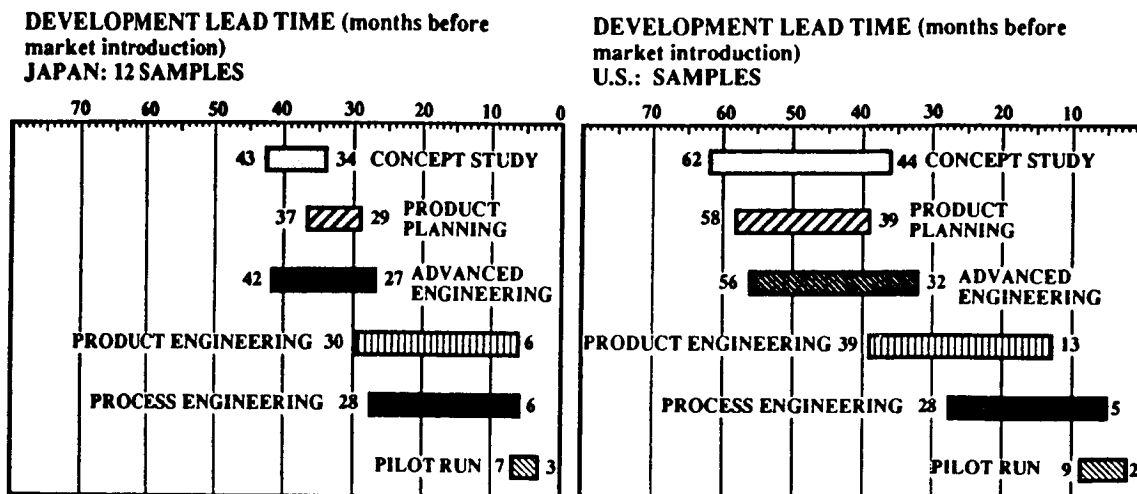
#### **BUILD IT RIGHT**

IN-PROCESS MONITORING  
STATISTICAL PROCESS CONTROL  
CONTINUOUS PROCESS  
IMPROVEMENT

## STME RELIABILITY AND SAFETY

### CONCURRENT ENGINEERING (Cont'd)

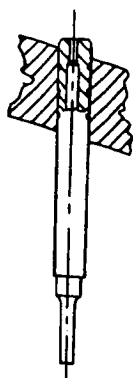
- **CAN SHORTEN PRODUCT DEVELOPMENT LEAD TIME**
  - OVERLAPPING PROBLEM-SOLVING INSTEAD OF SEQUENTIAL PHASES
  - AVERAGE PRODUCT LEAD TIME FOR JAPANESE AUTO MAKERS IS 43 MONTHS, COMPARED TO 62 MONTHS IN U.S.
  - RESULT IS BETTER PRODUCT AT LOWER COST



REFERENCE: PROFESSOR K. CLARK, HARVARD BUSINESS SCHOOL, 1987

## STME RELIABILITY AND SAFETY

### IMPACT OF CONCURRENT ENGINEERING ON ROCKETDYNE STME MAIN INJECTOR ELEMENTS

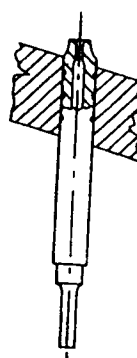


- Drilled from solid bar
- All surfaces require machining

Estimate for 600 elements

400 Hours

*Original Concept*



- Made from heavy wall tubing
- Swage one end to achieve entrance diameter
- Bulk of tube requires no I.D. Machining

Estimate for 600 elements

204 Hours

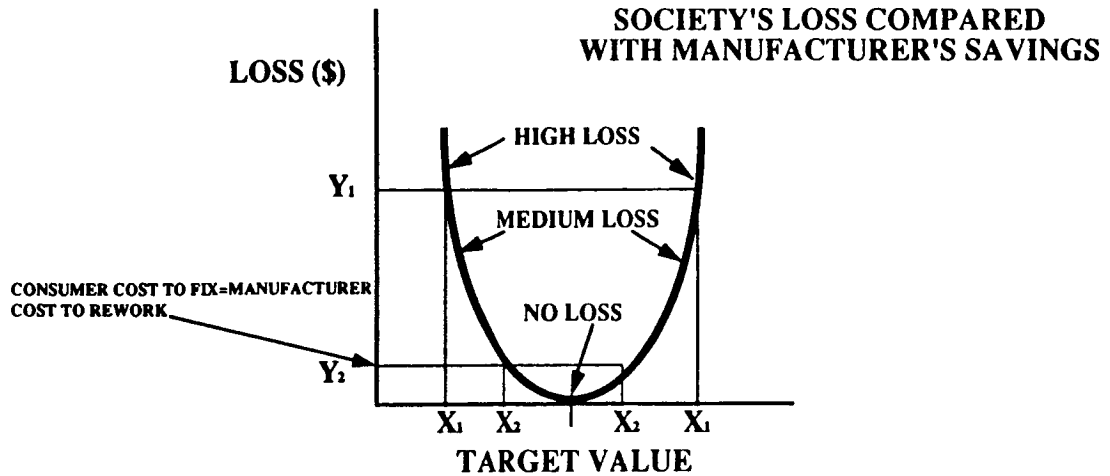
*After Concurrent Engineering*

**FEWER OPERATIONS =  
LESS CHANCE OF ERROR =  
IMPROVED RELIABILITY**

## STME RELIABILITY AND SAFETY

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### TAGUCHI LOSS FUNCTION



*THE PHRASE "GOOD ENOUGH FOR  
GOVERNMENT WORK" ISN'T GOOD ENOUGH ANYMORE*

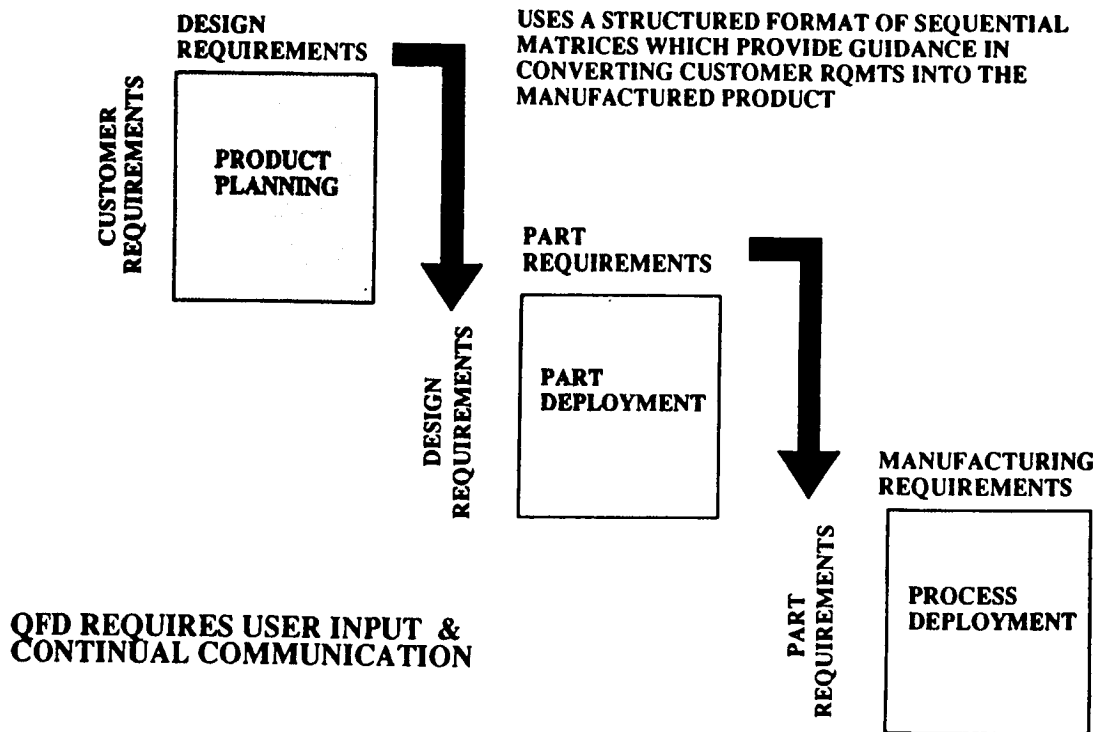
## STME RELIABILITY AND SAFETY

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**REDUCING PROCESS VARIABILITY PRODUCES A  
PRODUCT WITH IMPROVED RELIABILITY AND SAFETY**

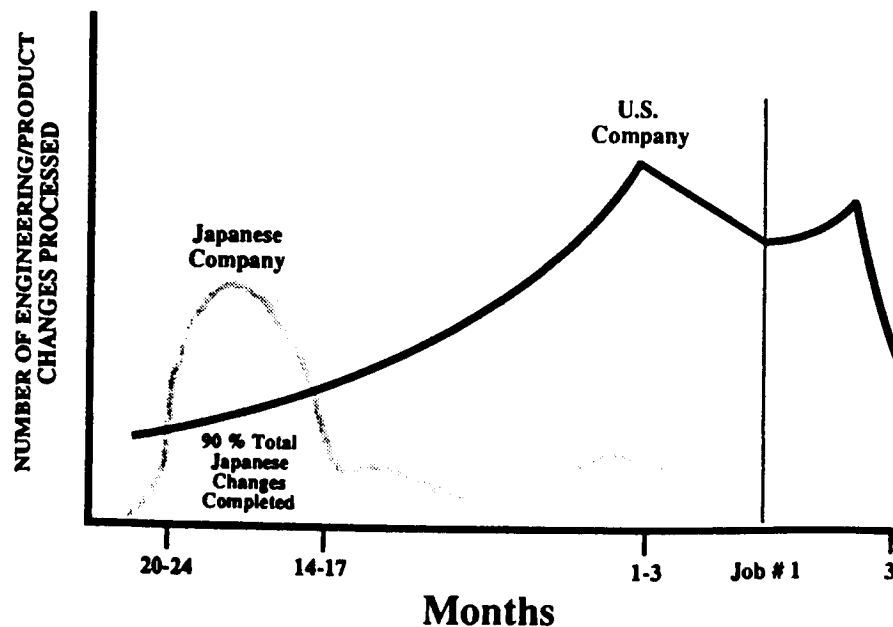
**REDUCED PROCESS VARIABILITY =  
IMPROVED RELIABILITY AND SAFETY**

## QFD MATRICES



## STME RELIABILITY AND SAFETY

### IMPACT OF EARLY DEFINITION AND ENGINEERING



# **STME RELIABILITY AND SAFETY**

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## **QUALITY ENGINEERING**

# **STME RELIABILITY AND SAFETY**

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## **DESIGNED EXPERIMENTS**

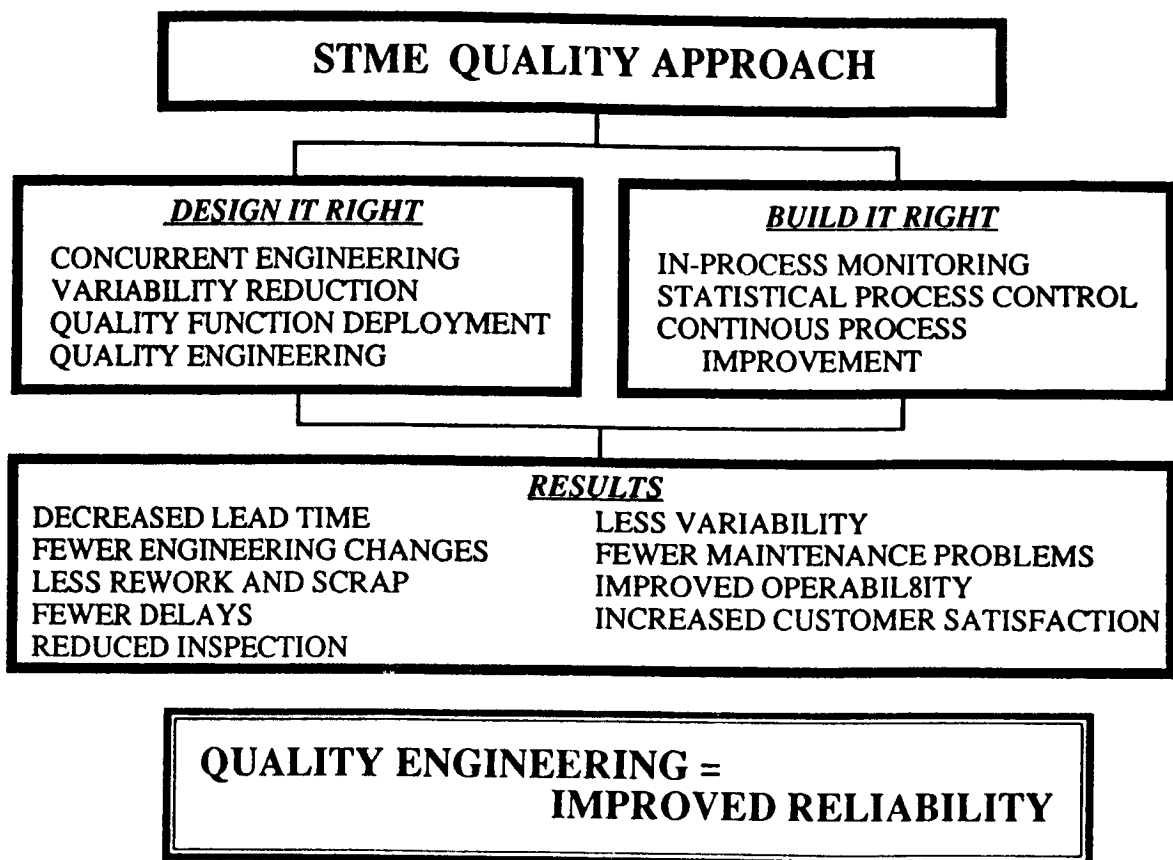
**DEFINITION: THE PURPOSEFUL CHANGES TO THE INPUTS OF A PROCESS IN ORDER TO OBSERVE CORRESPONDING CHANGES IN THE OUTPUT.**



**USING DOE, YOU CAN:**

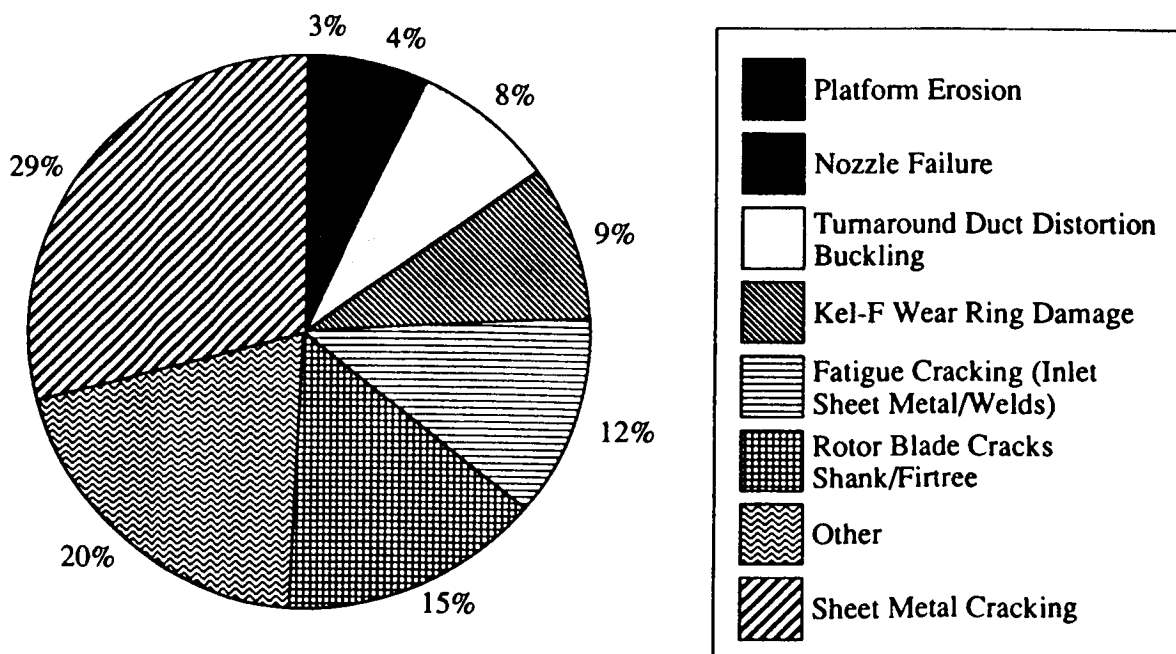
- 1. OBTAIN THE MAXIMUM AMOUNT OF INFORMATION USING THE MINIMUM AMOUNT OF RESOURCES**
- 2. DETERMINE WHICH FACTORS SHIFT THE AVERAGE RESPONSE , WHICH SHIFT THE VARIABILITY, & WHICH HAVE NO EFFECT**
- 3. FIND FACTOR SETTINGS THAT OPTIMIZE THE RESPONSE AND MINIMIZE THE COST**

## STME RELIABILITY AND SAFETY



## STME RELIABILITY AND SAFETY

### SSME HPFTP PREDOMINANT FAILURE MODES





## STME RELIABILITY AND SAFETY

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### SIMPLIFIED DESIGNS - P & W FUEL TURBOPUMP *FUEL TURBOPUMP COMPARISON TO SSME*

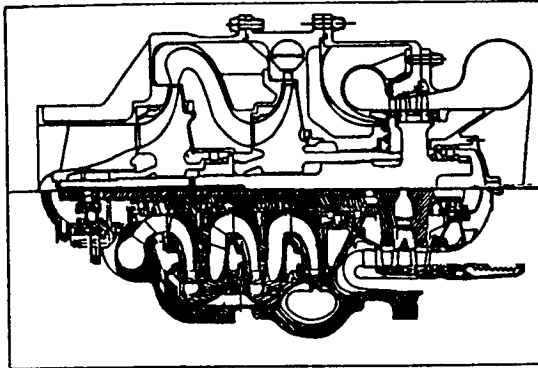
#### STME

PART NOS. - 48  
PARTS COUNT - 374  
WELD COUNT - 0  
PROTECTIVE COATINGS - NO  
DISK GOLD PLATING - NO  
WELD OVERLAYS - NO

2 STAGE PUMP  
CAST IMPELLERS  
2 BEARINGS - SIMPLE ROTOR SUPPORT  
SYSTEM COMMON FASTNERS & SEALS

1447 HOLLOW BLADES  
SIMPLE TURBINE OD WALL  
NO SHEET METAL LINERS  
NO INTERNAL BELLOWS LINER

AXIAL INLET  
  
VOLUTE INLET



#### SSME

PART NOS. - 169  
PARTS COUNT - 1041  
WELD COUNT - 169  
PROTECTIVE COATINGS - YES  
DISK GOLD PLATING - YES  
WELD OVERLAYS - YES

6 BEARINGS - COMPLEX ROTOR SUPPORT  
3 STAGE PUMP  
MACHINED IMPELLERS  
UNIQUE SEALS & FASTNERS

SOLID BLADES  
BELLOWS LINER  
WELDED SHEET METAL LINERS  
COMPLEX TURBINE OD WALL

## STME RELIABILITY AND SAFETY

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### ENGINE SYSTEM DESIGN CHARACTERISTICS THAT IMPROVE RELIABILITY

- SERIES TURBINES
- MECHANICALLY LINKED GG VALVES
- OPEN LOOP CONTROL
- DESIGN MARGINS
- LOW TURBINE TEMPERATURES
- NO BLEED SYSTEM
- FIXED OR DUAL THRUST MODE
- NOT WEIGHT CRITICAL

## STME RELIABILITY AND SAFETY

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### ALL CANDIDATE ENGINE CYCLES UTILIZE SERIES TURBINE ARRANGEMENT

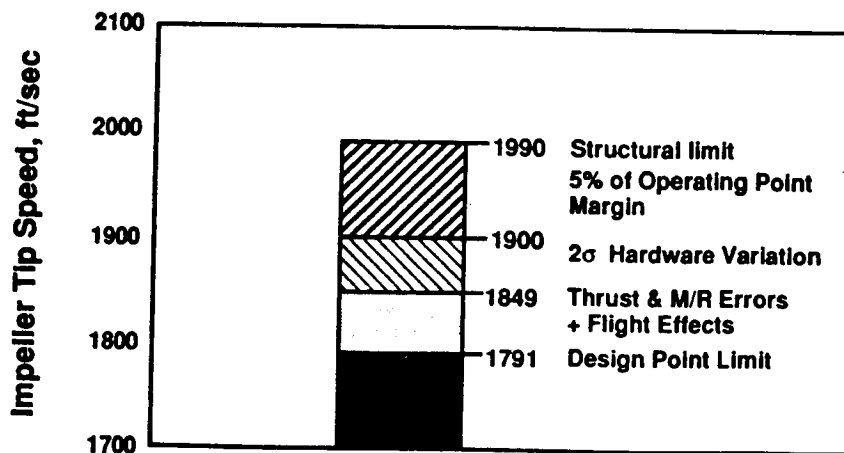
- **SIGNIFICANT RELIABILITY IMPROVEMENT  
OVER PARALLEL TURBINE ARRANGEMENT**
  - FUEL TURBINE BLOCKAGE REDUCES LOX  
TURBINE AVAILABLE HORSEPOWER
  - LOX TURBINE CANNOT POWER UP INDEPENDENT OF  
FUEL TURBINE

## STME RELIABILITY AND SAFETY

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### MDC PARAMETER DERIVATION EXAMPLE

#### FTP Impeller Tip Speed



## STME RELIABILITY AND SAFETY

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